Joint Call Admission Control and Resource Allocation for H.264 SVC Transmission over OFDMA Networks

M.Z. Bocus, J.P. Coon, C.N. Canagarajah, J.P. McGeehan, S.M.D. Armour and A. Doufexi

Centre for Communications Research

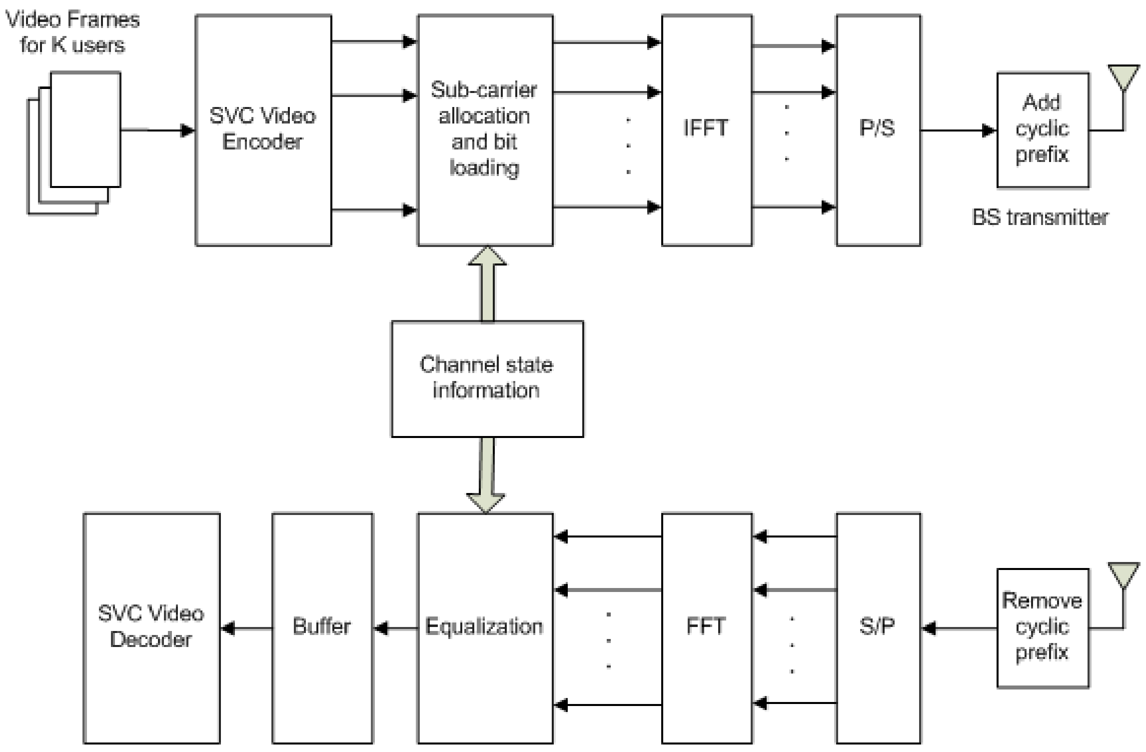
Presentation Overview

- **Motivation**
- **System model**
- **Overview of H.264 SVC**
- **Conventional resource allocation problem formulation**
- **Joint CAC and resource allocation**
- **Results and conclusion**

Motivation

- Increasingly high data rate transmission now possible
- Multimedia communication occupying increasing portion of spectrum share
- OFDMA is candidate for many future wireless transmission technologies

System Model – Block diagram



- Downlink scenario
- *K* video sequences transmitted over a total of *N* subcarriers
- Maintain QoS within power budget

Overview of H.264 SVC

- **Each scalable sequence consists of one base layer and a number of enhancement layers**

- **Why SVC ?**
  - More robust to packet losses/errors
  - Adaptive to fluctuating bandwidth
  - Supports heterogeneous devices

Overview of H.264 SVC

Illustration of scalable video coding

Resource Allocation Problem

- **Adaptively perform bit loading and subcarrier allocation**

Problem Formulation

- ***maximize***

  sum rate across all users

- ***subject to***

  - rate achieved for each user is in the allowed set
  - no subcarrier is shared by more than one user
  - each user must transmit at least the base layer
  - total power limit should not be exceeded

IP Formulation of Problem

$$
\begin{aligned}
\text{maximize} \quad & \sum_{n=1}^{N}\sum_{k=1}^{K}\sum_{c=0}^{M-1} c\rho_{k,n,c} \\
\text{subject to} \quad & \sum_{n=1}^{N}\sum_{c=0}^{M-1} c\rho_{k,n,c} - \sum_{l=1}^{L} z_{k,l} = 0, \quad \forall k \\
& \sum_{l=1}^{L} z_{k,l} = 1, \quad \forall k \\
& \sum_{k=1}^{K}\sum_{c=0}^{M-1} \rho_{k,n,c} \le 1, \quad \forall n \\
& \sum_{n=1}^{N}\sum_{k=1}^{K}\sum_{c=0}^{M-1} \frac{f_k(c)}{|h_{k,n}|^2}\rho_{k,n,c} \le P_T \\
& \rho \in \{0,1\}, z_{k,l} \in \{0,1\}
\end{aligned}
$$

where

$f_k(c)$ is the power required for transmitting *c* bits if channel gain is unity at a target BER of P_e
$|h_{k,n}|^2$ is the channel gain on the *n*th subcarrier of user *k*
P_T is the total power available for downlink

Resource Allocation Problem

- **Problem is formulated as a binary integer program**
- **BUT, in general ...**

Integer programs are *NP* hard ! !

- **Numerous sub-optimal algorithms presented in the literature for adaptive subcarrier allocation and bit loading**

Resource Allocation Problem

- **Existing resource allocation algorithms for multimedia transmission assume all users can be supported**

- **In practice, number of calls would vary**
  - Highly inefficient to run solve the allocation problem each time number of connection changes

- **Solution ...**
  - Perform call admission control and resource allocation jointly

Maximize number of supported users and maintain QoS

Proposed CAC

- **2 –step approach**

- ***STEP 1***
  - **Assume fixed modulation**

  - **Admit maximum number of users based on base layer rate and available power**

- ***STEP 2***
  - **Adaptive bit loading to increase number of supported video layers**
  - **Note: Aim is NOT to increase transmission rate !!!**

CAC – Step 1

1. Arrange users in descending order according to their average channel gain
2. Set $p_{used} = 0$, where p_{used} is the power required for transmission
3. Set $k = 1$
4. Calculate the power required to transmit on the n_k best subcarriers of user k
5. Update p_{used}
6. if $p_{used} > P_T$

   $k = k - 1$

   Stop, maximum number of calls supported is $K^* = k$

   Exit algorithm
7. **else**

   $k = k + 1$

   Remove subcarriers used by user k, from further allocation
8. Go to step 4.

CAC – Step 2

Adaptive bit loading

1. **initialisation:** $k = 1$, $l = 2$
2. Evaluate $p_{\setminus k}$
3. Adaptively load bits on subcarriers in S_k
   until layer l can be transmitted
4. Calculate additional power necessary for transmitting layer l
   of user k, p_{add}
5. **if** $p_{add} + p_{\setminus k} > P_T$
      Stop and exit algorithm
6. **else**
      if $k = K^*$
         $l = l + 1$
         $k = 1$
         Go to step **2**
      else
         $k = k + 1$
         Go to step **2**

RESULTS

Results

- **Comparison between maximum number of supported users with proposed CAC and optimal solution**

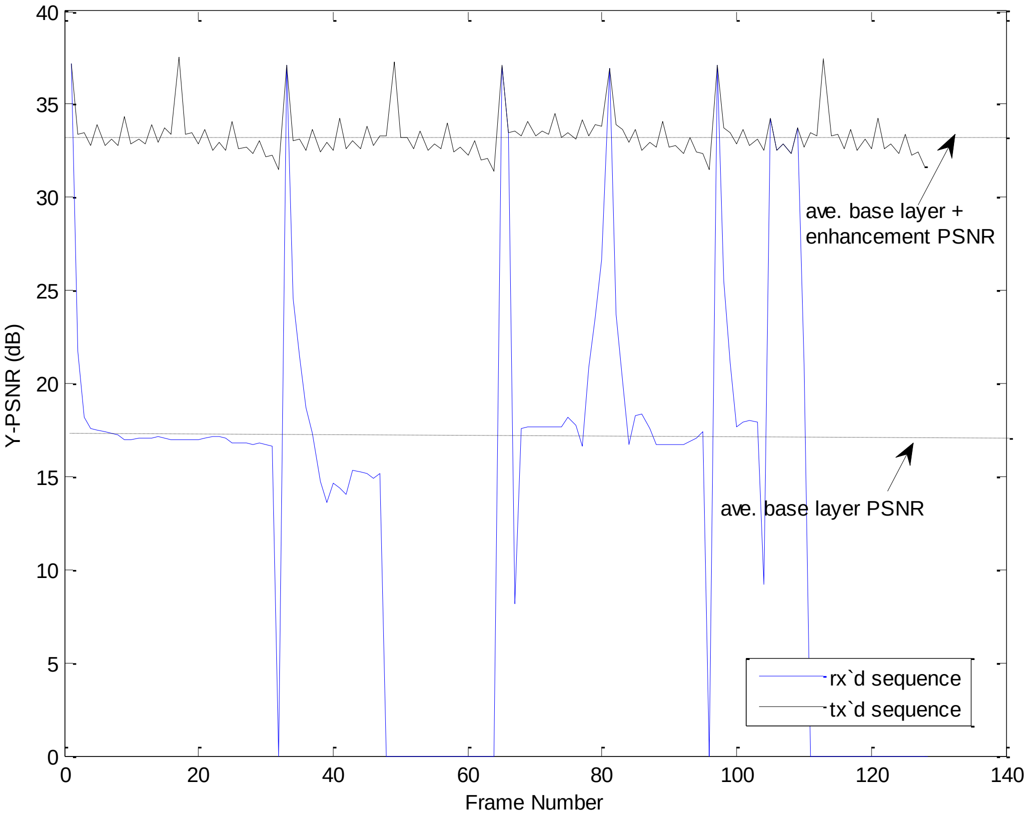
- **For optimal case, it may be required to solve the IP multiple times**

AVERAGE NUMBER OF SUPPORTED USERS

Approach	$N = 8$	$N = 16$
Optimal	3.25	8.0
Proposed CAC	2.214	5.8

Results

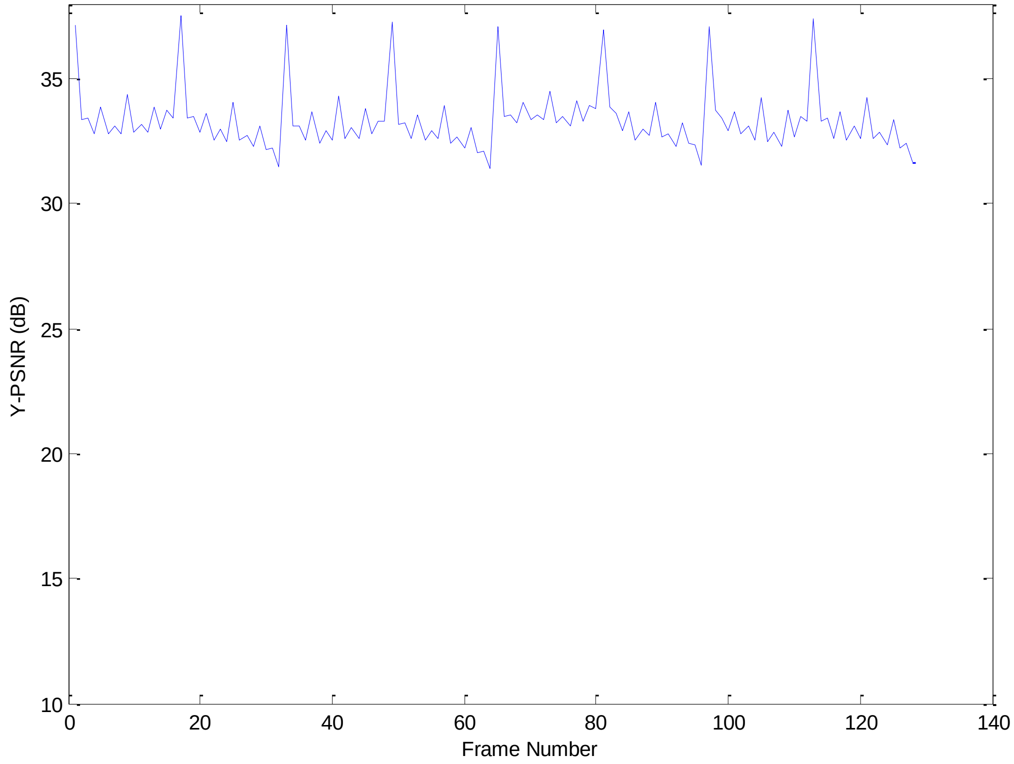
Non- Channel-aware resource allocation



- **'bus' sequence encoded in 2 spatial layers**
- **CIF format 30 fps**
- **N=256 subcarriers, , *K* =6 users**
- **CNR = 22 dB**
- **QPSK modulation**
- **Exponentially decaying channel with decay factor 0.86**

Results

Proposed CAC and resource allocation



- CNR = 18 dB, target $P_e = 10^{-8}$
- 'bus' sequence
- All video layers correctly received

Conclusion

- **Proposed scheme ensures that all users allowed into the system can achieve QoS**

- **Fair scheme – more power allocated to users with poor subcarriers**

- **Higher video quality compared to non-channel aware resource allocation**

- **For small systems, number of calls permitted close to the optimal case**

THANK YOU

Basics of SVC